W Production in Association with Jets at Hadron Colliders

W+b & W+light jets

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Summary

1. Associated Production of a *W* and one *b-jet*
   - Merging 4FNS and 5FNS NLO computations
   - Results for Tevatron and LHC
   - The CDF data "puzzle"

With: *John Campbell, Keith Ellis, Fabio Maltoni, Laura Reina, Doreen Wackeroth and Scott Willenbrock*
arXiv:0809.3003

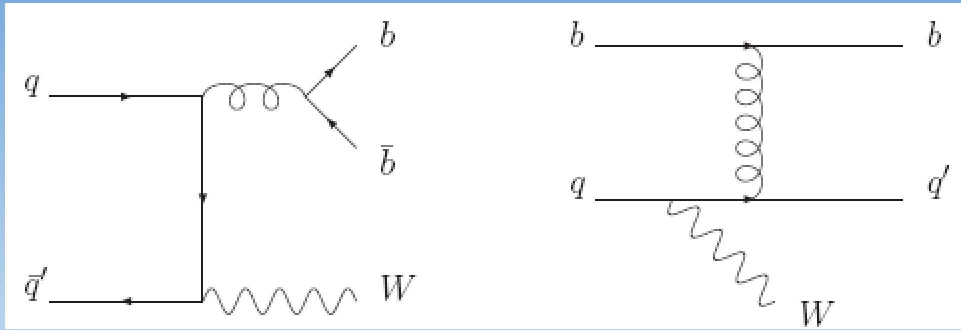
2. NLO corrections to *W*+ n jets (n=1,2,3)
   - NLO corrections with BlackHat+SHERPA
   - Comparing to CDF data
   - LHC results

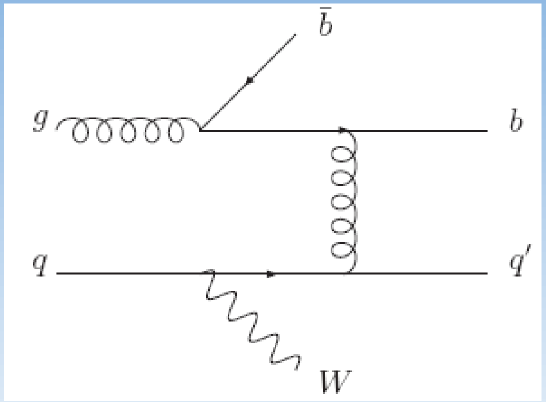
With: *C.F. Berger, Z. Bern, L. Dixon, D. Forde, T. Gleisberg, H. Ita, D. Kosower and D. Maitre*
arXiv:0902.2760

3. Conclusions

W+b at NLO

- Many precision studies performed for single gauge boson production in association with jets one of which is massive (*V+Q+n j*)
- An obvious omition: *W+b*





Full description needs combination of computations for *W+b+j and W+2 b (with m_b≠0)!*

W b + X: *divide et impera*

W bb (FF)	W bj (VF)
$q\bar{q}' \to Wb\bar{b}$	$bq \to Wbq'$
$q\bar{q}' \to Wb\bar{b}g$	$bq \to Wbq'g$
	$bg \to Wbq'\bar{q}$
$gq \to Wb\bar{b}q'$	$gq \to Wb\bar{b}q'$

[FFC,Reina,Wackeroth]
hep-ph/0606102

[Campbell,Ellis,Maltoni,Willenbrock]
hep-ph/0611348

W b+X & W(bb) + X @ NLO (VF)

W+b at hadron colliders

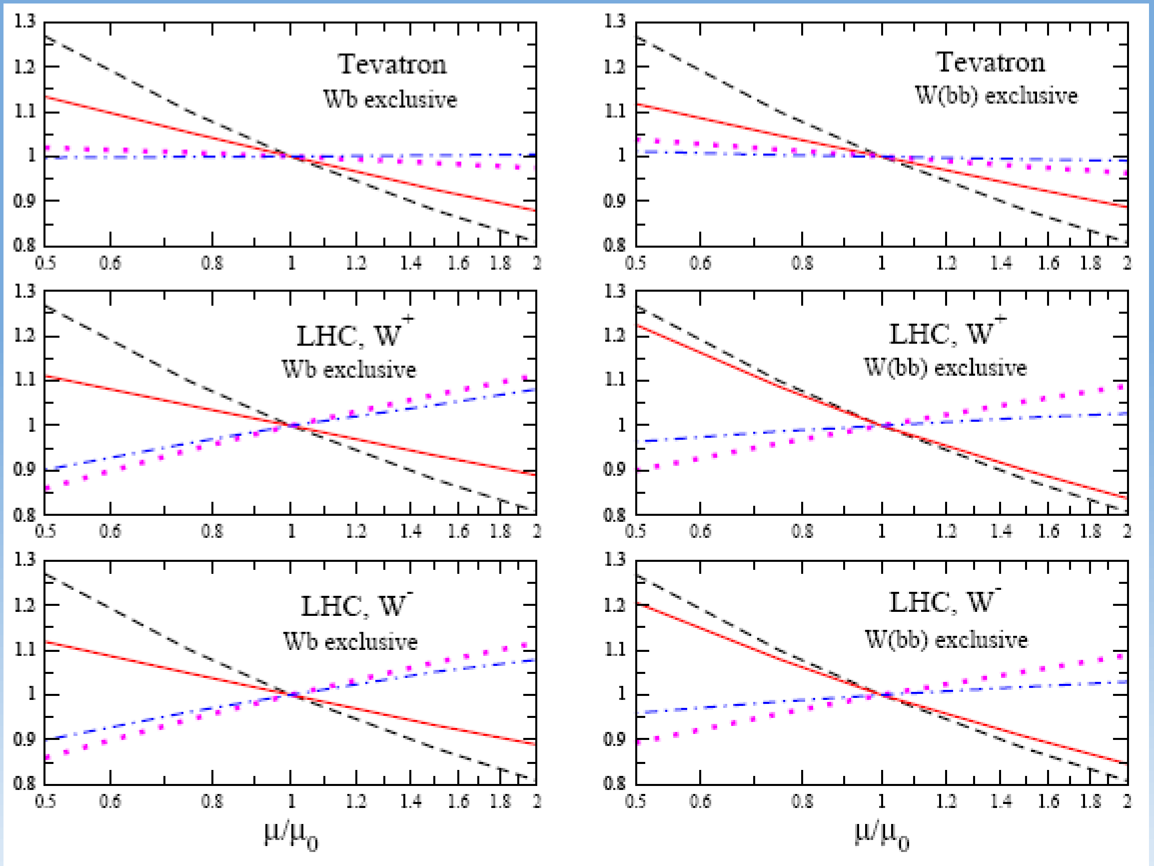
- Complementarity of the approaches: Total cross sections at the Tevatron and LHC

Tevatron:	$p_{Tj} > 15$ GeV	$\|\eta_j\| < 2$
LHC:	$p_{Tj} > 25$ GeV	$\|\eta_j\| < 2.5$
$\|\Delta R_{b\bar{b}}\| > 0.7$		$\|\Delta R_{bj}\| > 0.7$

	Exclusive cross sections (pb)	
Collider	Wb	$W(bb)$
TeV $W^+(=W^-)$	[5.28+0.75=6.03] 8.02+0.62=8.64	[2.66] 3.73-0.02=3.71
LHC W^+	[30.2+54.3=84.5] 40.0+48.4=88.4	[17.6] 22.7+11.7=34.4
LHC W^-	[21.6+31.4=53.0] 29.8+29.4=59.2	[12.9] 17.2+6.5=23.7
	Wj	
TeV $W^+(=W^-)$	[1410] 1790	
LHC W^+	[14240] 15810	
LHC W^-	[11040] 12040	

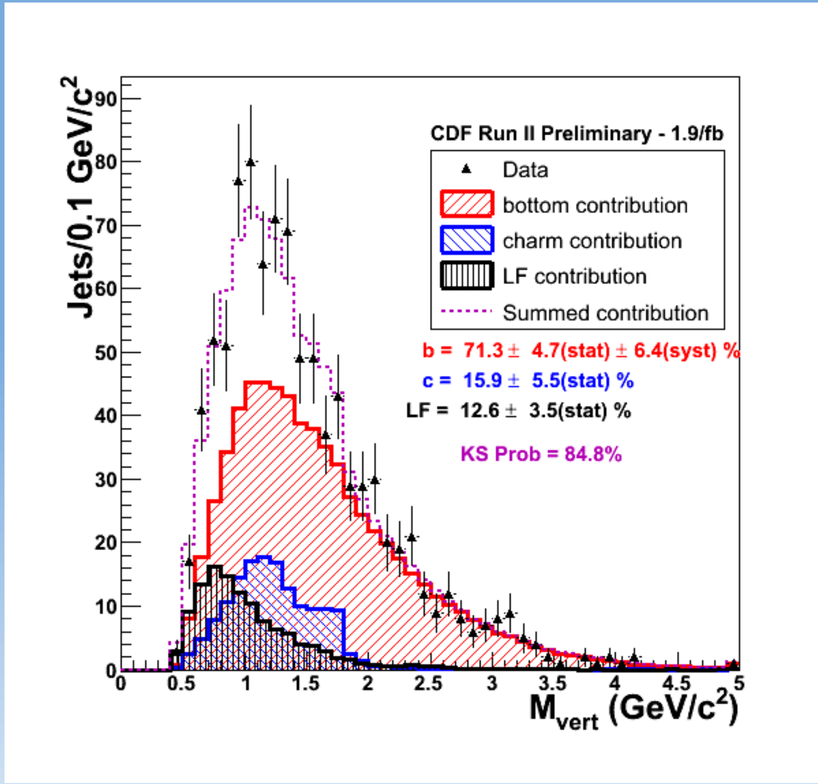
Merging allows consistent treatment at the differenct kinematical regimes!

And the common reduction in Scale Uncertainty:



CDF Measurement of the b Jet Production Cross Section in Events with a W$^{\pm}$ Boson

http://www-cdf.fnal.gov/~neu/wbjets_1900_public/



Under internal CDF review for PRL submision

Prediction	$\sigma_{b-\text{jets}}(W + b\text{-jets}) \times BR(W \to \ell\nu)$(pb)
ALPGEN	0.78

$\sigma_{b\text{-jets}}$ (W+b-jets) · BR($W \to l\, \nu$) = 2.74 ± 0.27 (stat) ± 0.42(syst) pb

A puzzle?

Prediction	$\sigma_{b-\text{jets}}(W+b\text{-jets}) \times BR(W \to \ell\nu)$(pb)
ALPGEN	0.78

jet cross section

$\sigma_{b\text{-jets}}(W+b\text{-jets}) \cdot BR(W \to l\,\nu) = 2.74 \pm 0.27 \text{ (stat)} \pm 0.42\text{(syst) pb}$

From NLO:

	Wb		$W(b\bar{b})$	
Bin	LO	NLO	LO	NLO
1 jet	$0.88\,^{+0.28}_{-0.19}$ (0.82 + 0.06)	$1.23\,^{+0.13}_{-0.14}$ (1.18 + 0.05)	$0.20\,^{+0.07}_{-0.04}$	$0.26\,^{+0.02}_{-0.04}$ (0.26 + 0.00)
1+2 jets	$1.30\,^{+0.41}_{-0.29}$ (1.15 + 0.15)	$1.80\,^{+0.21}_{-0.21}$ (1.63 + 0.17)	$0.20\,^{+0.07}_{-0.04}$	$0.32\,^{+0.06}_{-0.05}$ (0.29 + 0.03)

event cross section

2.12 (± 0.22) pb

(Lower bound for jet cross section)

(C.F. Berger, Z. Bern, L. Dixon, FFC
D. Forde, T. Gleisberg, H. Ita,
D. Kosower and D. Maitre)

W+n j (n=1,2,3) at NLO

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See talks by:

- *Frank Krauss*
- *Darren Forde*
- *Harald Ita*

W+Jets at the Tevatron: CDF Analysis

T. Aaltonen et al. [CDF Collaboration], arXiv:0711.4044, 320 pb^-1

	Cut
Electron Et	20 GeV
Electron eta	1.1
Missing Energy	30 GeV
W Transverse Mass	20 GeV
Jet Et	20 – 25 GeV
Jet eta	2
Delta R	0.4

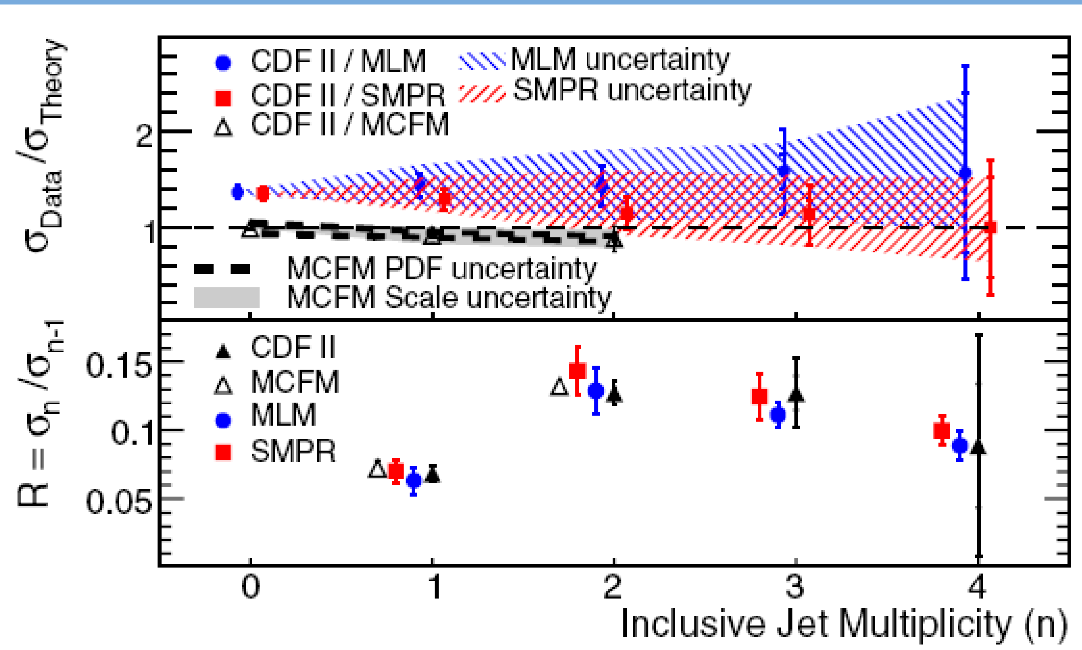
We employ the SISCone Jet Algorithm

Salam, Soyez arXiv:0704.0292

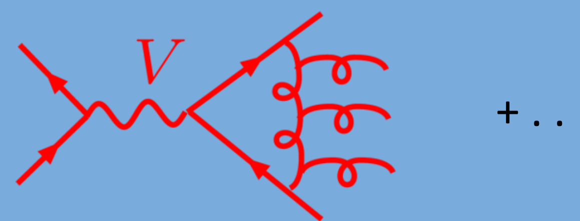
CTEQ pdfs, and a dynamical factorization/renormalization scale (sqrt(Mw^2+pt_W^2)) for comparison with data

Comparing tools

T. Aaltonen et al. [CDF Collaboration], arXiv:0711.4044



Wanted: LHC studies with extra jets:



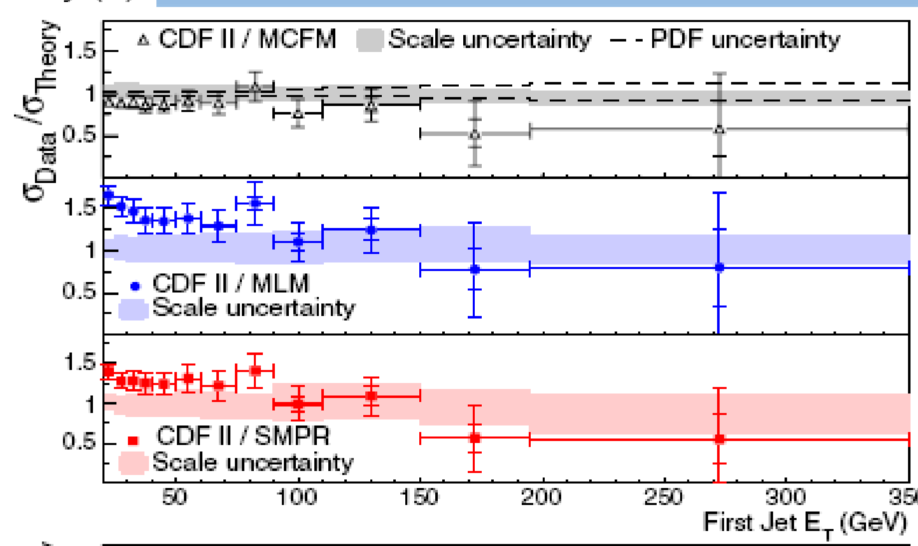
data from $320 pb^{-1}$

SMPR-model: Madgraph+Pythia
MLM-model: Alpgen+Herwig

} LO,

MCFM; parton level; including Bern, Dixon, Kosower, Weinzierl 1-loop matrix elements; Full NLO by Campbell and Ellis

} NLO.



W+n jets: Comparing Rates

number of jets	CDF	LC NLO	NLO
1	53.5 ± 5.6	$58.3^{+4.6}_{-4.6}$	$57.8^{+4.4}_{-4.0}$
2	6.8 ± 1.1	$7.81^{+0.54}_{-0.91}$	$7.62^{+0.62}_{-0.86}$
3	0.84 ± 0.24	$0.908^{+0.044}_{-0.142}$	$0.882(5)^{+0.057}_{-0.138}$

PRELIMINARY

Reduction in Scale Dependence

Number of jets	LO	NLO
1	16%	7%
2	30%	10%
3	42%	12%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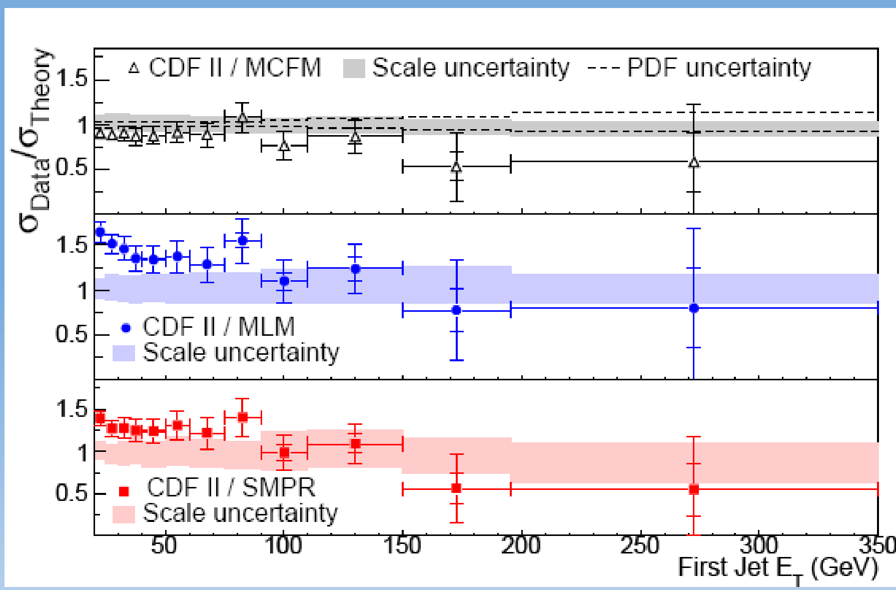
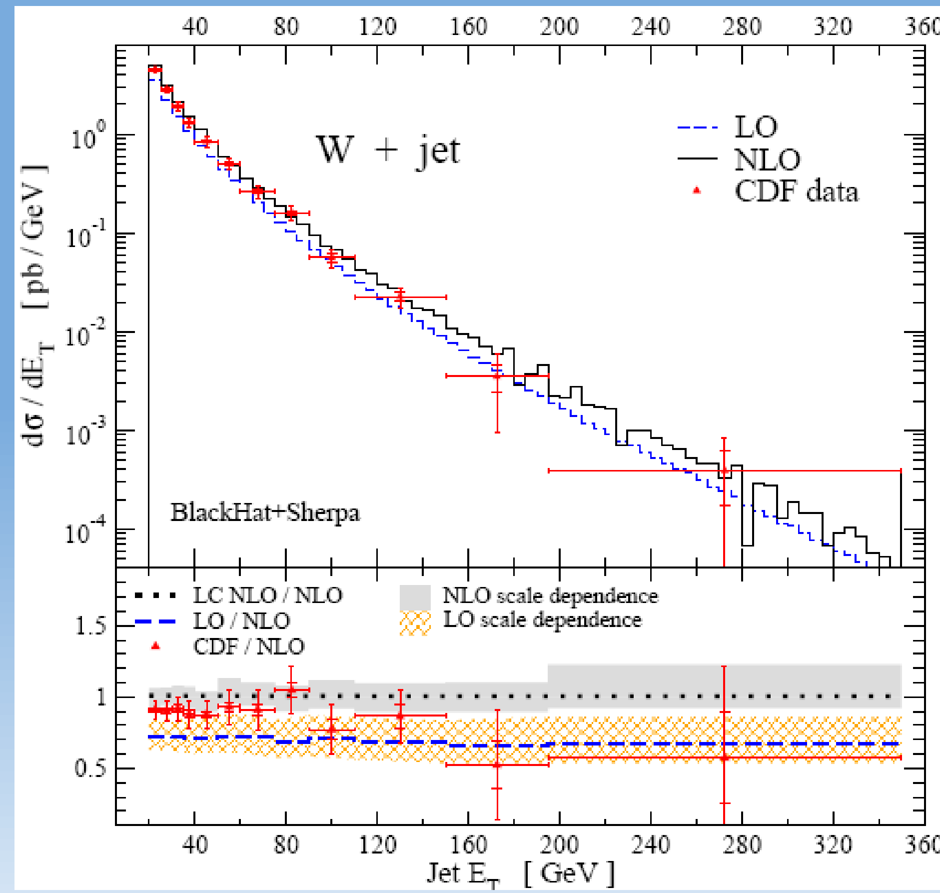
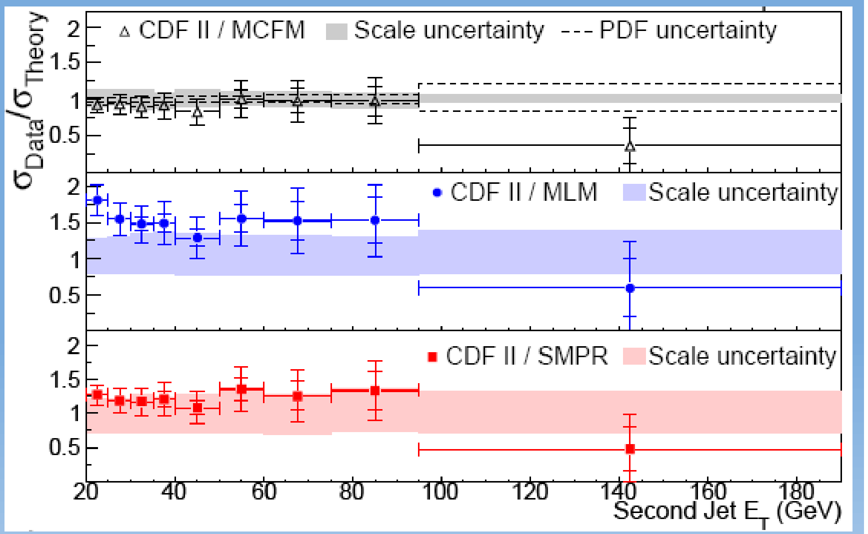
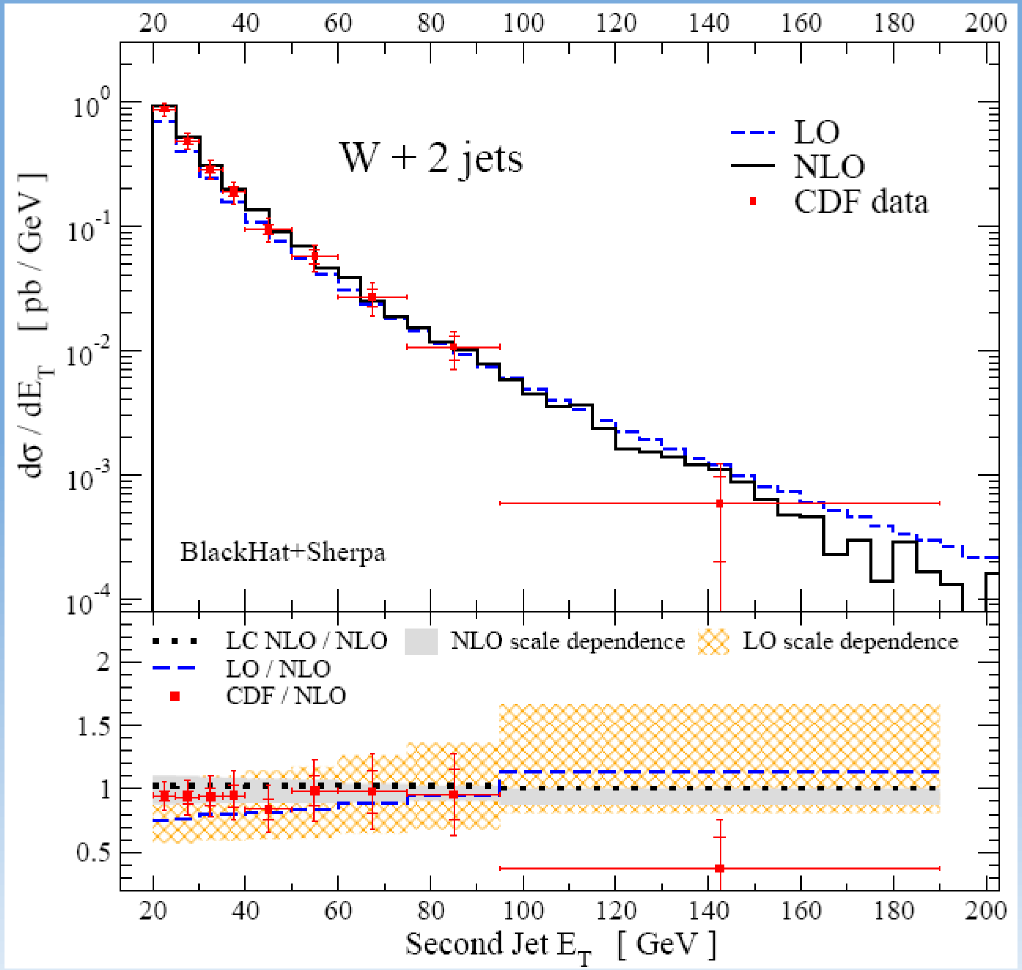
W+ jet +X at the Tevatron



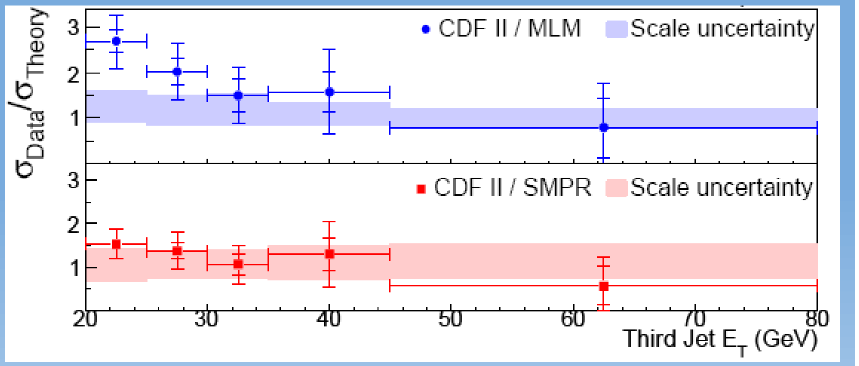


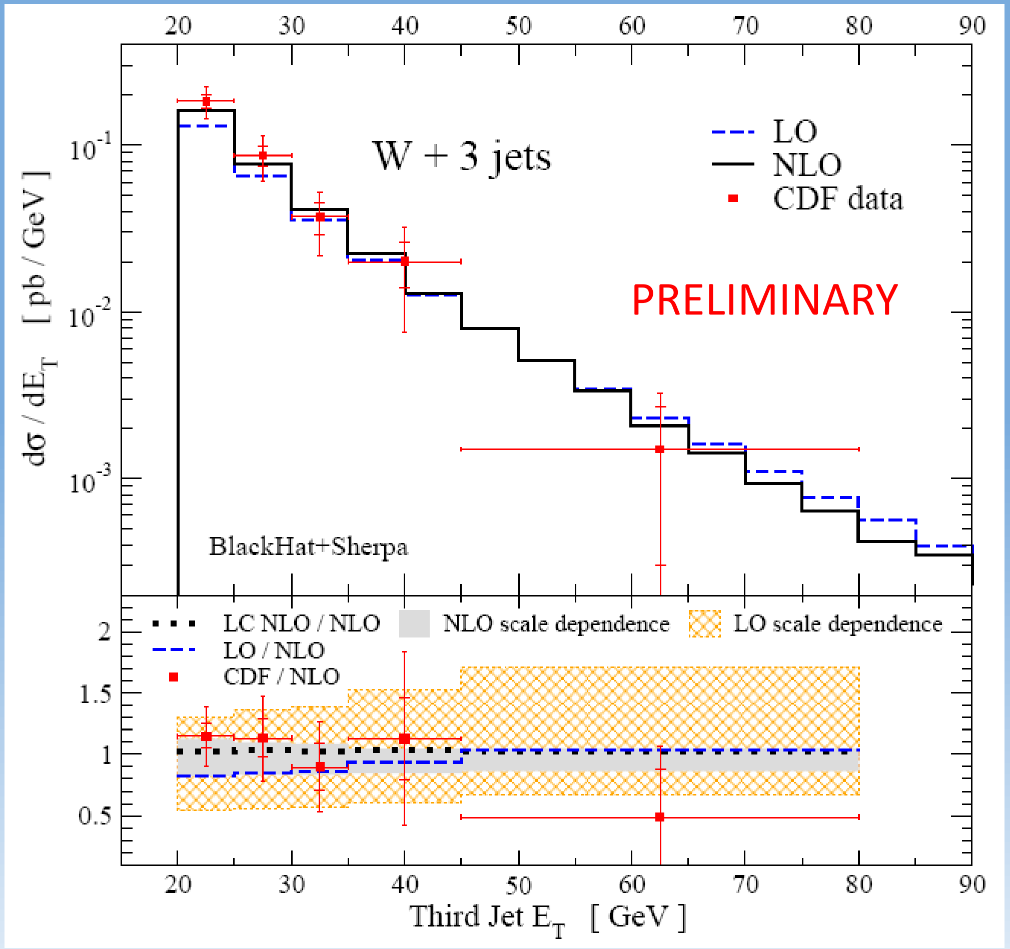
W+2 jets + X at the Tevatron





W+3 jets + X at the Tevatron





W+3 Jets at the LHC

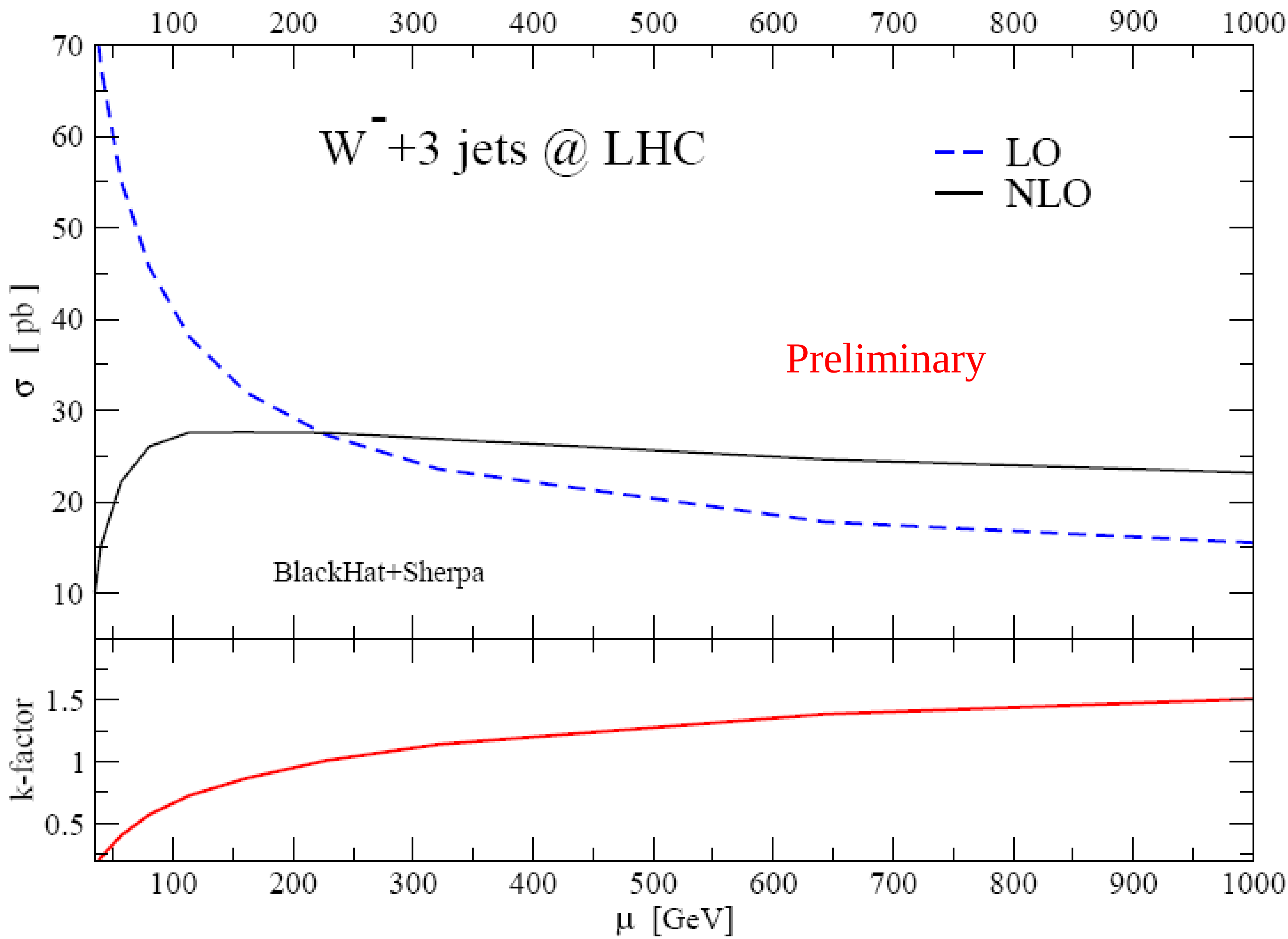
PRELIMINARY

	Cut
Electron Et	20 GeV
Electron eta	2.5
Missing Energy	30 GeV
W Transverse Mass	20 GeV
Jet Et	30 GeV
Jet eta	3
Delta R	0.4

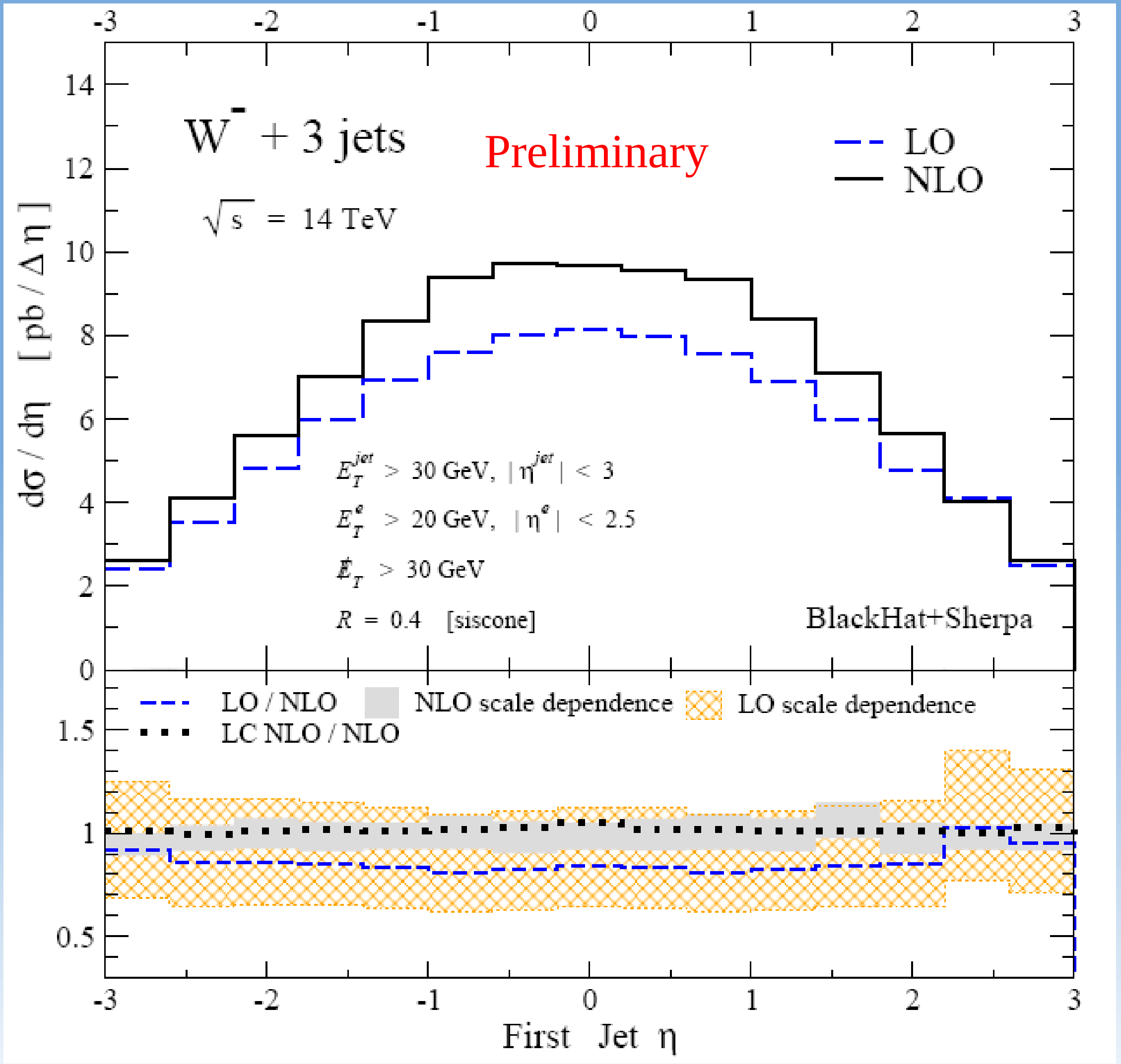
$$E_{CM} = 14\ \mathrm{TeV}$$

SISCone

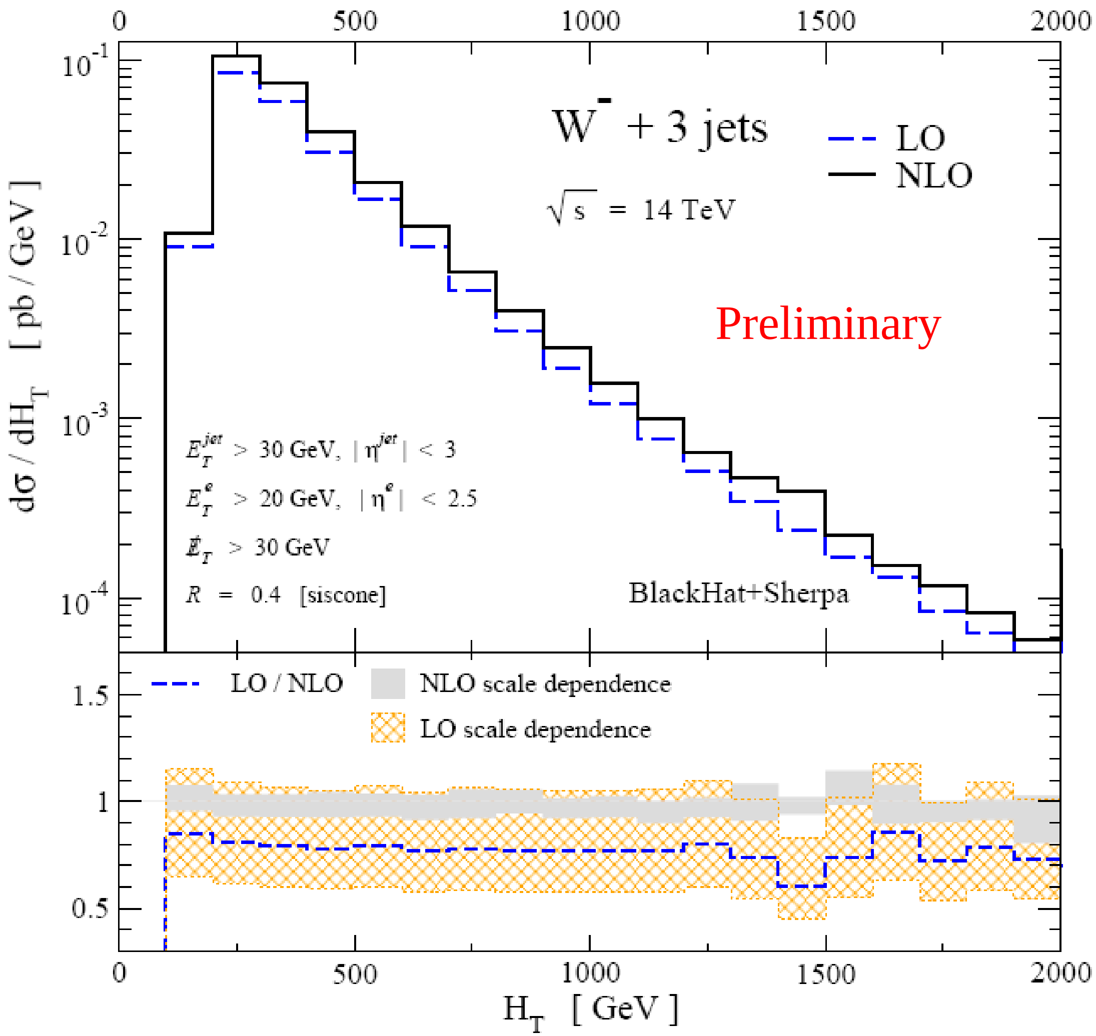
LHC total cross section



First jet eta distribution

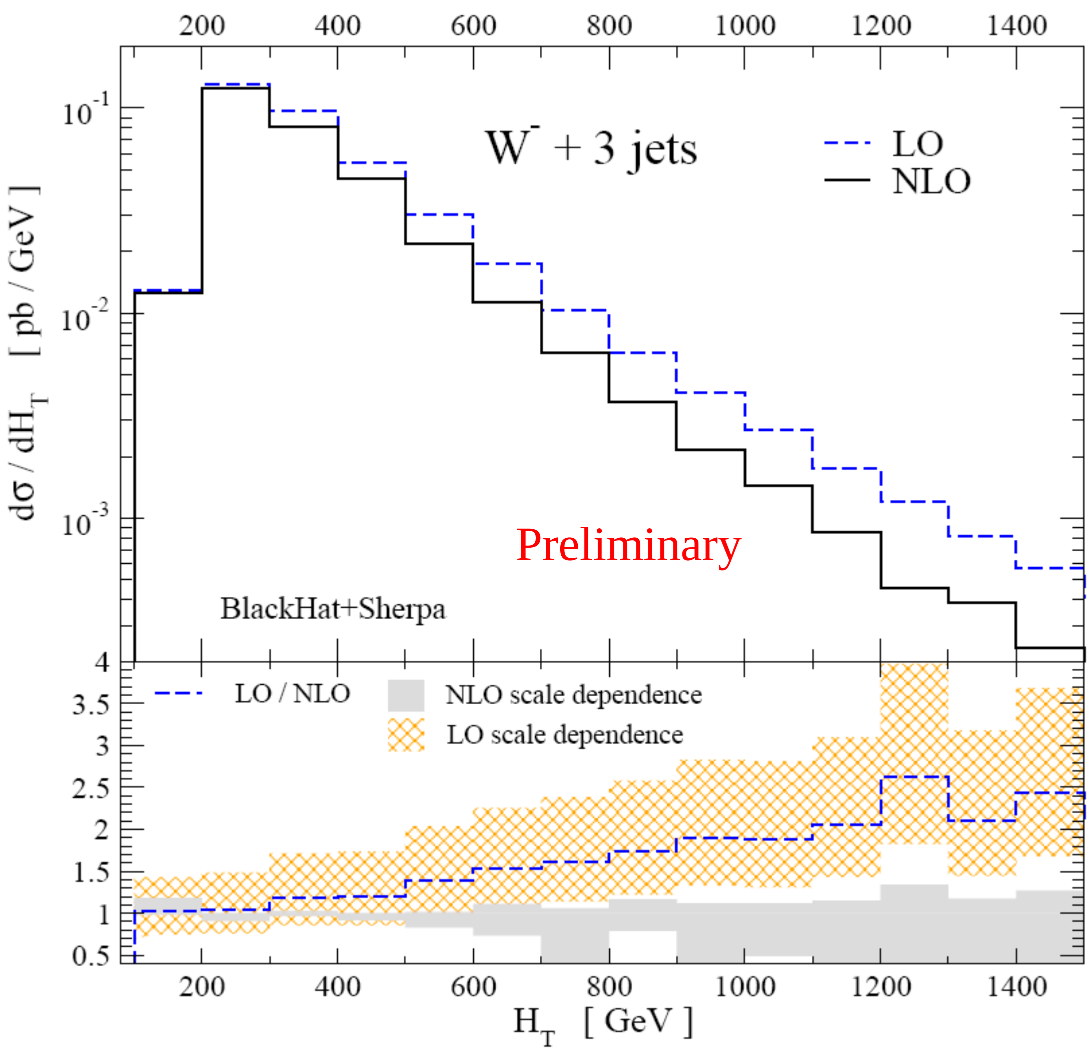


$H_T = \sum_j E_{T,j}^{\rm jet} + E_T^e + \not{E}_T$ distribution



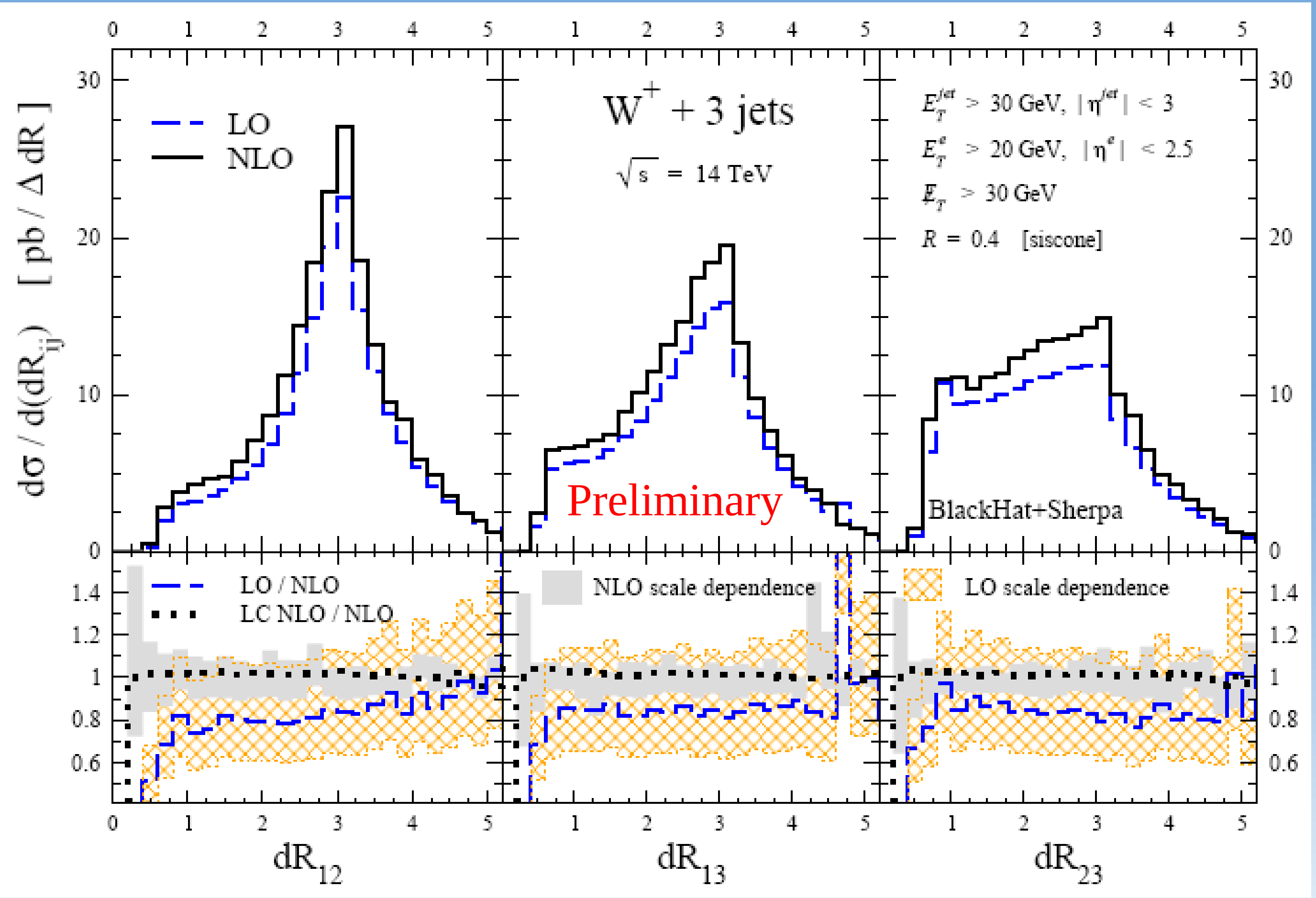
mu = H_T

$H_T = \sum_j E_{T,j}^{\text{jet}} + E_T^e + \not{E}_T$ distribution



$\mu = \sqrt{M_W^2 + p_T^2(W)}$

Jet dR Distributions



Conclusions & Outlook

- Presented results for ***W+b*** production including NLO QCD corrections
- Comparison against ***CDF data*** is under way, but preliminary results are promising.
- On-shell methods have opened a new gate to computational power in QFTs
- With BlackHat+SHERPA we have presented first full (preliminary) NLO results for ***W+3*** production.
- W+3 (as well as W+1 and W+2) predictions agree well with CDF data, scale uncertainty greatly reduced!
- Look forward for more studies of relevant processes for hadron colliders!